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Evaluation of fish population estimation by removal sampling in King's Creek, Kansas

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EVALUATION OF FISH POPULATION ESTIMATION BY REMOVAL SAMPLING IN KINGS CREEK

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Abstract

Population estimation is an integral part of fisheries science. Using electrofishing to conduct a multiple-pass depletion-removal method to estimate population parameters is common. However, this method is time consuming and labor intensive. Recent research suggests that, under certain circumstances, reliable population estimates from a single-pass electrofishing event can be obtained. The objectives of this study were 1) to determine if fish density and catch-per-unit-effort (CPUE) from a single-pass electrofishing event is correlated with population density estimates obtained from the depletion-removal method and 2) to describe relationships among habitat variables and probability of capture from electrofishing. The study was conducted on Kings Creek, within Konza Prairie Research Natural Area in the Flint Hills region of eastern Kansas. Two species of fish, southern redbelly dace (*Phoxinus erythrogaster*) and central stoneroller (*Campostoma anomalum*), were studied. Significant correlations were found between CPUE and estimated density (fish/m^2) and first-pass catch density and estimated density ($r^2 = 0.42$, $p = 0.03$; $r^2 = 0.85$, $p = 0.0001$, respectively) for southern redbelly dace but not for central stonerollers ($r^2 = 0.37$, $p = 0.06$; $r^2 = 0.30$, $p = 0.1$, respectively). There were no significant correlations between any of the measured habitat parameters and probability of capture for either species. These results suggest that it would be effective and time-efficient to use first-pass catch values as an index to abundance of southern redbelly dace populations in Kings Creek. However, first-pass catch values may not adequately index density of central stonerollers.

Introduction

It is important to obtain accurate estimates of fish density and relative abundance for management recommendations or evaluations (Layher and Maughan 1984). Common techniques include gill nets, seines, underwater observations, poisons, explosives and electric current. These techniques, coupled with mark-recapture or depletion-removal protocols, or direct counts from underwater observation have shown to be effective methods of estimating population size. Unfortunately, each of these procedures is time consuming and expensive (Lobón-Cervía and Utrilla 1993, Zaleweski 1983). In addition, there are biases in variation and catchability of fish in different habitat types using different gear (Layher and Maughan 1984,Vadas and Orth 1993, Larimore 1961, Zaleweski 1983). Each sampling situation may require a different technique. For example, Jones and Stockwell (1995) suggest that snorkeling is preferred when details of microhabitat distribution are of interest, mark-recapture is most effective when a population estimate is needed for a sparse population over a large area, and depletion-removal is practical in small streams. Also, Wiley and Tsai (1983) state that although the mark-recapture method is theoretically superior to the depletion-removal method, the depletion-removal method is more effective in small rivers with small fish.

Electrofishing, first utilized in the late nineteenth century (Reynolds 1996), is a widely used technique for river fisheries (Zalewski 1983). Electrofishing is the use of an electric current to stun fish, causing them to become temporarily immobilized and float to the surface of the water for capture (Reynolds 1996). According to Zaleweski and Cowx (1989), electrofishing is the most effective, non-destructive population sampling procedure for fish in small-to-medium-sized streams. Another positive aspect of electrofishing is that fish mortality and injury rates are low (Pusey et al. 1998). However, Jones (1995) states that electrofishing "necessitates a fishing procedure that is slow, methodical and consistent." The usual techniques of electrofishing for population estimates include a minimum of three passes for a depletion-removal estimate including from twenty to forty-five minutes for the river or stream bottom to settle between passes.

Recently, much research has focussed on the reliability of sampling with electrofishing to estimate population density (Kruse 1998). Although most studies claim it is necessary to use the multiple-pass depletion method for population sampling (Pusey et al. 1998), several recent studies have shown that in small-to-medium-sized streams with low physical impedence, it is possible to obtain a reasonable population estimate with a single electrofishing pass (Kruse et al. 1998, Jones and Stockwell 1995, Lobón-Cervía and Utrilla 1993, Hayes and Baird

1994). Jones and Stockwell (1995) suggest using the one-pass procedure to increase the number of sites included in surveys when a fixed amount of time is available for data collection. By doing this, additional sites can be sampled and scientists can have a more statistically valid sampling scheme and a more extensive survey. However, variability in electrofishing efficiency depends greatly on the sample site and there are no general rules for setting appropriate protocols (Larimore 1961, Cross and Stott 1975, Jones and Stockwell 1995). Jones and Stockwell (1995) suggest that individual crews should standardize their procedures because each crew uses different equipment, works in streams of ranging physical characteristics and studies fish with varying catchabilities.

In this study, I assessed the efficiency of single-pass electrofishing in Kings Creek on the Konza Prairie Natural Research Area. Specifically, I wanted to determine if first-pass catch and catch-per-unit-effort (CPUE) could accurately predict multiple-pass population density estimates. In addition, I wanted to describe potential relationships between probability of capture and habitat complexity of the stream. I expected that there would be a strong positive correlation between first-pass catch and estimated density from a multiple-pass depletion method as well as a positive relationship between CPUE and estimated density from a multiple-pass depletion method. I also expected that there would be significant correlations between probability of capture and habitat complexity. Probability of capture should be lower in deeper streams, wider streams and where there is more physical habitat obstruction.

Methods

Site Description

Kings Creek is located in the Flint Hills region of northeastern Kansas, approximately ten miles south of Manhattan, Kansas (39°05'N, 96°35'W); it flows into McDowell creek which then flows to the Kansas River (Oviatt 1998). The Kings Creek Basin, which encompasses 1,059 hectares (Oviatt 1998), lies entirely within the 3,487 hectare Konza Prairie Research Natural Area (KPRNA). Kings Creek has a substrate composed mainly of limestone and chert gravel, pebble and cobble. Riparian vegetation of Kings Creek consists of prairie grasses and forbs in the headwaters; grasses, forbs, shrubs and small trees in the mid-reaches; and gallery forests along the lower reaches of the stream. The forests are dominated by *Quercus macrocarpa* (bur oak), *Q. muhlenbergii* (chinquapin oak), *Celtis occidentalis* (hackberry), and *Ulmus* (elm) species. Monthly average air temperatures range from a low of -2.7°C in January to a high of 26.6°C in July. Mean annual precipitation is 835 mm with 75% occurring during the growing season (Gray *et al.* 1998).

Sampling

All sampling of Kings Creek was completed during June and July, 1999. I sampled 10 sites, two of which were sampled twice, once before and once after a flood in mid June (Figure 1). Sites were sampled in upper, middle and lower reaches. Each site included a system of riffles and pools, with riffles as natural barriers at both ends in order to keep fish population closed (Hayes and Baird 1994, Larimore 1961).

Fish Population Sampling

Electrofishing was conducted with a gasoline powered Coeffelt electrofishing backpack shocking unit (Honda EX 350 150-350 V DC) with an anode ring attached to a pole and cathode wire cable. Voltage was set to maintain 4-6 amperes depending on the substrate and subsequent water conductivity. These values were set to adequately stun fish while maintaining low mortality rates.

Electrofishing was conducted with a three-person team, commencing downstream and walking upstream through the site until the end of the last riffle or pool. One person carried the electrofishing unit while two people carried dip nets. If the width of the site was narrow enough for the team to reach both sides, the team walked straight up the stream; if the width was wider across than the three people, the team moved upstream in a zig-zag manner. All stunned fish were netted and placed in five-gallon buckets filled with stream water, which had been placed along the site. I recorded total electrofishing effort (minutes spent electrofishing) after each pass.

All fish were identified, recorded and returned to the stream downstream from the sampling site. Young-of-the-year fish were not sampled because they were too small to be captured in the dip nets. Approximately 20 minutes were allowed to lapse before commencing the next pass in order to allow the water to become less turbid. All subsequent passes proceeded in the same way. A minimum of three and a maximum of four passes were completed at each site depending on number of fish captured during the third run. If the captures depleted with each subsequent pass enough to obtain a linear regression, we stopped at three passes.

Habitat Assessment

After the electrofishing was completed, I assessed stream habitat following Gorman and Karr (1978) and Schlosser (1982). At each site, I measured length and width of each pool and riffle. Habitat was measured in three dimensions: depth, substrate and other possible fish habitat. Each riffle or pool was divided into three transects at approximately 25%, 50% and 75% of its length. At each transect, three even spaced point samples were taken for depth and substrate measurements along its width. Substrate was assigned to one of seven categories according to dominant particle size (Table 1). Other fish habitat parameters were classified as area of stream covered by woody debris, undercut banks, or overhanging vegetation.

Calculations and Statistical Analysis

Population estimates and probability of capture values were calculated using the computer program Population Estimation by Removal Sampling® (Pisces Conservation, Ltd., United Kingdom) based on the Zippin removal method (Zippin 1956).

All correlations were analyzed using linear regressions in the JMP® (SAS Institute, Inc., Cary, North Carolina) statistical program. For the southern redbelly dace, one sample was excluded from calculations and for the central stoneroller, two samples were excluded. These samples were removed because population estimates were unreliable: either sample size was too small or captures did not decrease sufficiently enough with each subsequent pass for an accurate regression line to be obtained.

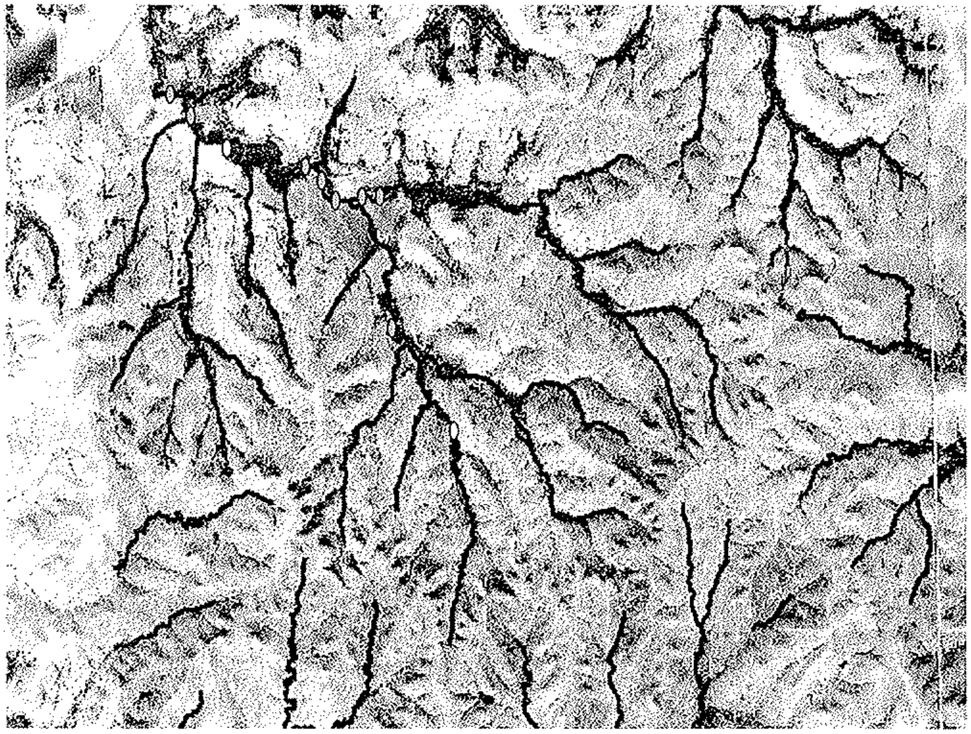

Figure 1- Aerial view of Kings Creek Basin with sites sampled. North is up. Grey ovals indicate sites sampled once. White ovals indicate sites sampled twice.

Results

Electrofishing Population Estimates

Eleven species of fish were captured (Table 2), the most abundant being southern redbelly dace (*Phoxinus erythrogaster*) and central stonerollers (*Campostoma anomalum*).

Population estimates for southern redbelly dace varied from 8-282, densities varied from $0.05/m^2$-$1.6/m^2$, and probability of capture varied from 0.2-0.62 (Table 3). Catch-per-unit-effort of southern redbelly dace from the first pass was significantly related to the corresponding density estimates from the multiple pass depletion method (Figure 2, r^2= 0.42, p= 0.03). The density estimates of southern redbelly dace from the first capture were significantly correlated with the corresponding density estimates from the multiple pass depletion method (Figure 3, r^2= 0.85, p= 0.0001). Total catch density estimate (estimate of site density based on total number of fish captured in all passes) was significantly related to the corresponding density estimates from the multiple pass depletion method (Figure 4, r^2= 0.96, p= 0.0001).

Population estimates for central stonerollers varied from 1-511, densities varied from $0.01/m^2$-$1.4/m^2$ and probability of capture varied from 0.11-1 (Table 3). Catch per unit effort of central stonerollers from the first pass was marginally significantly related to the corresponding density estimates from the multiple pass depletion method (Figure 5, r^2= 0.37, p= 0.06). Density estimates of central stonerollers from the first pass were not significantly correlated to the corresponding density estimates from the multiple pass depletion method (Figure 6, r^2= 0.30, p= 0.1). Total catch density estimate was significantly related to the corresponding density estimates from the multiple pass depletion method (Figure 7, r^2= 0.81, p= 0.0004).

Because of low numbers, it was very difficult to obtain reliable population estimates of any other species and no statistical analysis could be performed. The next most abundant species was the creek chub (*Semotilus atromaculatus*) which was found at eight of the ten sites (Table 2).

Habitat Assessment

There was slight variation in physical characteristics among the sites (Table 4), but I found no significant relationships between any habitat variables and probability of capture of *P. erythrogaster* or *C. anomalum* (Figures 8 and 9). For example, Figure 8 indicates that there is no relationship between area of physical impedence and probability of capture of southern redbelly dace. Figure 9 indicates that there is no relationship between probability of capture of southern redbelly dace and stream width. However, qualitative observations indicated that depending on the location of the woody debris (i.e. against the stream bank in the shade instead of in the middle of the stream in sunlight), the fish would congregate in the shelter of the habitat. This trend could not be documented quantitatively.

Table 1-Substrate Classifications for Kings Creek.

Category	Size
Clay	
Silt	
Gravel	<6.4 cm
Pebble	6.4-15.3 cm
Cobble	15.3-25.4 cm
Boulder	>25.4 cm
Bedrock	

Table 2 – Total number of each fish species captured and identified across all sites in Kings Creek.

Species Name / Site	1	2	3	4	5	6	7	8	9	10	11	12
Southern redbelly dace *Phoxinus erythrogaster*	68	131	106	123	207	70	6	81	41	64	107	105
Central stoneroller *Campostoma anomalum*	119	24	213	189	77	49	5	18	14	75	11	58
Creek chub *Semotilus atromaculatus*	42	0	11	12	8	2	1	3	1	2	0	11
Fathead minnow *Pimphales promelas*	0	0	4	0	0	1	0	0	0	0	0	0
Bluntnose minnow *Pimphales notatus*	2	0	0	1	0	0	0	0	0	0	0	0
Red shiner *Cyprinella lutrensis*	0	0	0	1	0	0	0	0	0	0	0	0
Common shiner *Luxilus cornutus*	2	0	0	0	0	0	0	0	0	0	0	0
White sucker *Catostomus commersonii*	13	0	0	0	0	0	0	0	0	4	0	2
Slender madtom *Noturus exilis*	0	0	0	0	2	1	0	0	0	0	0	0
Orangethroat darter* *Etheostoma spectabile*												
Johnny darter* *Etheostoma nigrum*												

*Indicates that species was present at all sites but not tallied.

Table 3- Mean, minimum and maximum population estimates, density estimates and probability of capture for southern redbelly dace and central stonerollers across all sites in Kings Creek.

	Population estimate (number of fish) from Population Estimation by Removal Sampling®			Density (fish/m^2)			Probability of capture		
Species	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Southern redbelly dace	119	8	282	0.61	0.05	1.6	0.44	0.20	0.62
Central stoneroller	54	1	511	0.43	0.01	1.4	0.48	0.11	1.0

Table 4- Site characteristics for ten sites of Kings Creek sampled. Two sites were sampled twice. Percent (%) boulder, etc. indicates the percentage of the substrate at the site composed of boulder. Woody debris consists of logs, branches, and woody roots in site. Total physical impedence consists of woody debris as well as undercut banks and overhanging vegetation.

Site	area (m^2)	mean width (m)	mean depth (m)	% boulder	% cobble	% pebble	% gravel	% silt	% clay	woody debris (m^2)	total physical impedence (m^2)
1	195.8	3.9	0.35	0	6	28	22	0	44	0.03	0.03
2	250.9	5.6	0.13	6	11	44	8	11	19	1.98	3.11
2 (2nd sampling)	70.9	1.5	0.15	0	19	39	28	0	14	0.73	0.86
3	359.2	4.8	0.19	0	8	42	22	0	28	0.74	0.74
3 (2nd sampling)	262.2	3.8	0.15	0	18	42	22	2	16	1.01	1.01
4	340.9	4.3	0.20	0	27	61	11	0	0	2.35	4.73
5	206.4	3.9	0.14	0	22	33	31	3	11	30.26	30.26
6	161.1	3.2	0.19	0	31	47	11	0	11	0.63	0.63
7	150.7	3.1	0.33	0	17	22	44	0	17	0.91	4.46
8	178.2	4.0	0.19	0	33	22	25	0	19	5.12	5.12
9	238.6	3.0	0.22	0	17	53	19	0	11	5.33	6.63
10	350.2	4.9	0.18	11	22	28	25	3	11	0.84	1.15
minimum	70.9	1.5	0.13	0	6	22	8	0	0	0.03	0.03
maximum	359.2	5.6	0.35	11	33	61	44	11	44	30.26	30.26
mean	230.4	3.8	0.20	1.4	19.3	38.4	22.3	1.6	16.8	4.2	4.89
st. dev	88.3	1.1	0.07	3.5	8.4	12.2	9.8	3.2	10.9	8.4	8.3

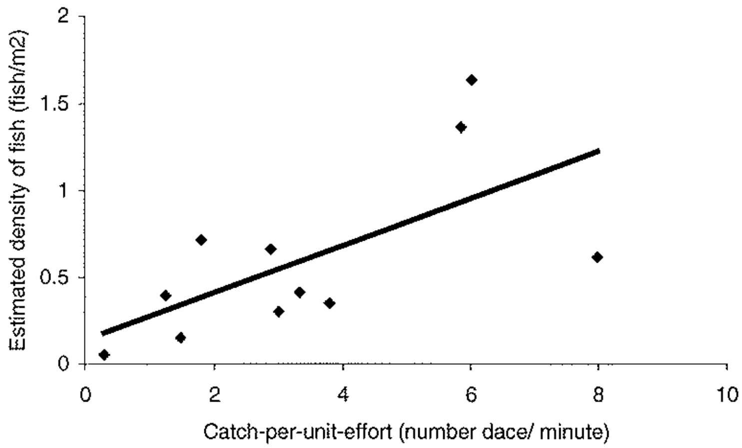

Figure 2- Catch-per-unit-effort (fish per minute) vs. estimated density of fish (fish/m^2) for southern redbelly dace (r^2= 0.42, p= 0.03). Density= 0.141+0.14(CPUE).

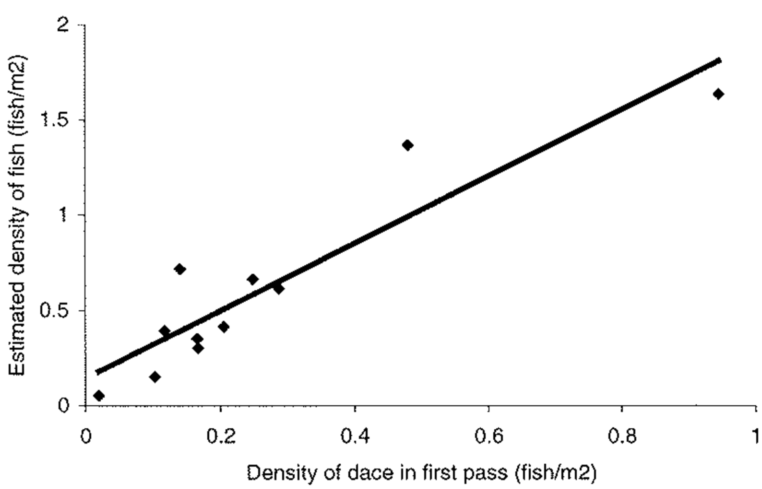

Figure 3- Density of southern redbelly dace in first pass catch vs. density of southern redbelly dace from estimated population (r^2= 0.85, p= 0.0001). Density= 0.145+1.76(First-pass-catch/m^2).

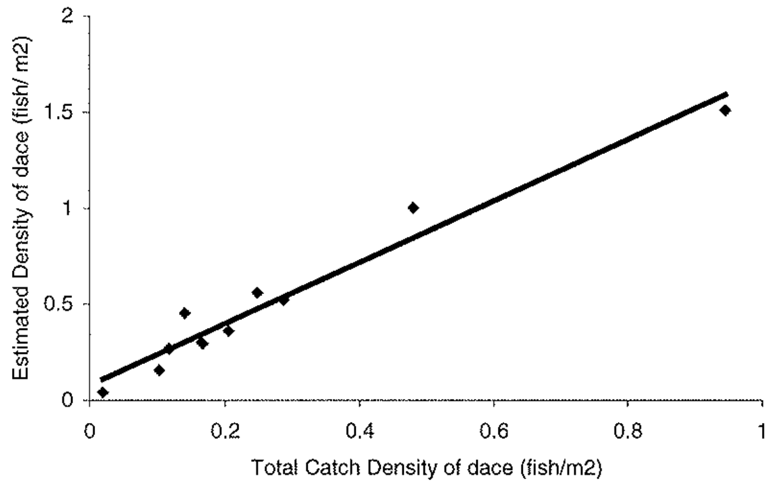

Figure 4- Density of southern redbelly dace from total catch density (fish/m^2) vs. estimated density of southern redbelly dace (fish/m^2) (r^2= 0.96, p= 0.0001).

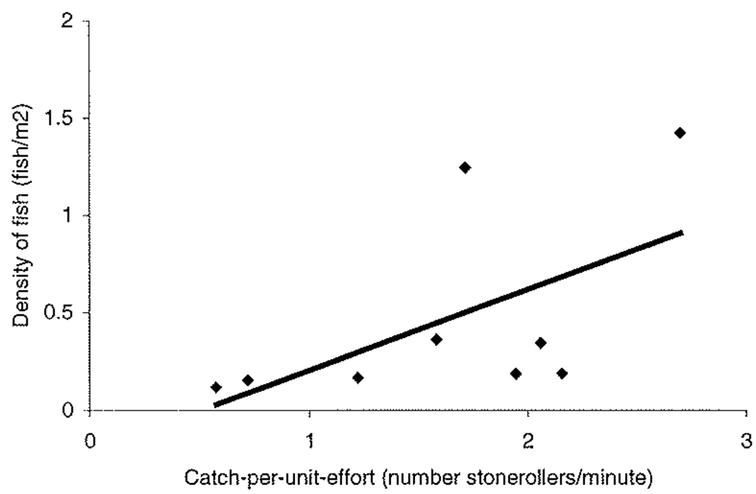

Figure 5- Catch-per-unit-effort (fish per minute) for central stonerollers vs. estimated density of fish (fish/m^2) for central stonerollers (r^2= 0.37, p= 0.06). Density= 0.267+0.439(CPUE).

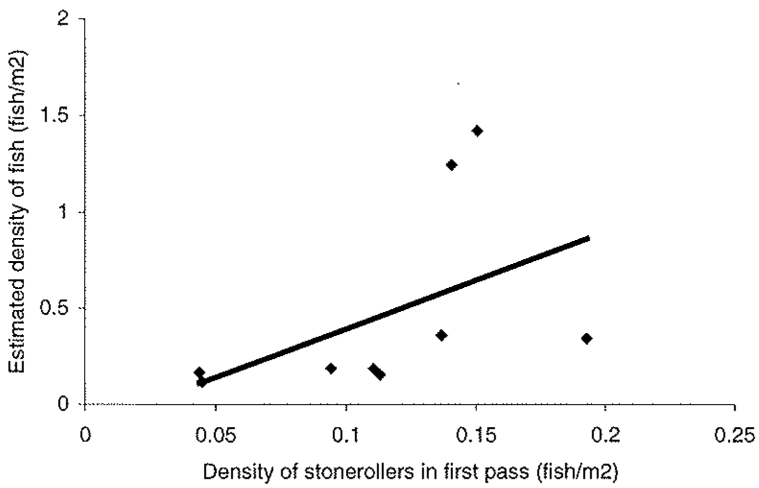

Figure 6- Density of central stonerollers in first pass catch vs. density of fish from estimated population of central stonerollers (r^2= 0.3, p= 0.1). Density= -0.074+ 4.77(First-pass-catch/m^2).

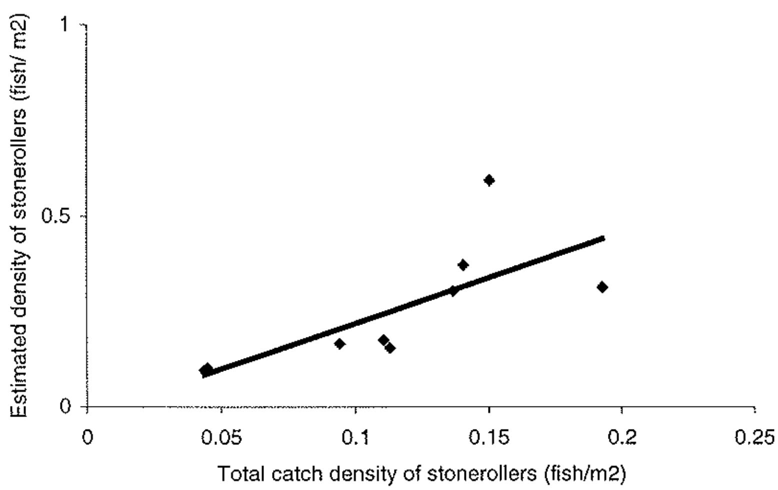

Figure 7- Density of central stonerollers from total catch (fish/m^2) vs. estimated density of central stonerollers (fish/m^2) (r^2= 0.81, p= 0.004).

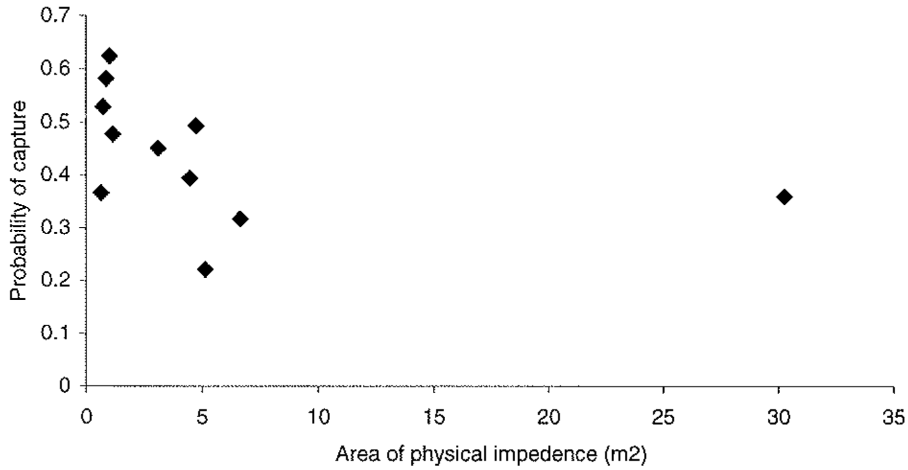

Figure 8- Area of physical impedence (woody debris, undercut banks and overhanging vegetation) vs. probability of capture of southern redbelly dace (r^2= 0.14, p= 0.26).

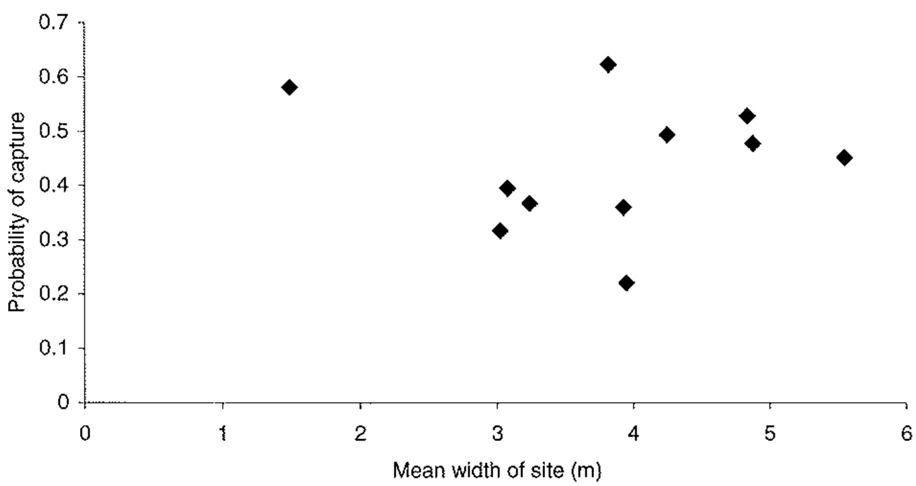

Figure 9- Mean width of site vs. probability of capture of southern redbelly dace (r^2= 0.002, p=0.966).

Discussion

In Kings Creek of northeastern Kansas, a relatively homogenous small stream, I observed that one electrofishing pass can provide an accurate index of fish density for the southern redbelly dace. As I expected, both CPUE and density of dace in the first pass (number caught on first pass/m^2) could reliably predict the population estimated from the multiple passes. The high correlation coefficients indicate that it would be accurate and highly beneficial to use these equations to estimate density of southern redbelly dace from a single pass in order to increase number of sites sampled, to save time, and to save money.

Several studies have shown that a single electrofishing pass cannot accurately predict fish abundance in streams (Mahon 1980, Bohlin and Sundstrom 1977, Schnute 1983, Bohlin et. al 1989, Riley and Fausch 1992). Conversely, several recent studies have shown that, in small streams with limited cover, a single electrofishing pass can accurately estimate trout population size (Jones and Stockwell 1995, Lobón-Cervía and Utrilla 1993, Strange et Al. 1989) or density (Kruse et al. 1998). Few studies have focussed on using this method to predict population density of other fish species. One Australian study showed that the first electrofishing pass poorly estimated the actual fish community structure (species composition) and that up to three passes were required for the estimate of community structure to stabilize (Pusey et al. 1998). A similar study concentrating on minnow families also indicates that a single electrofishing pass is not sufficient to estimate fish community structure, but notes that less sampling effort is required to estimate abundances (Angermeier and Smogor 1995).

Contrary to what I expected, neither CPUE nor density of fish caught on the first pass could accurately predict the multiple-pass population estimate for central stonerollers. There were two distinct outliers in the regression lines (See Figure 5 and Figure 6). At both of these sites, I experienced extremely high fish densities (1.42 and 1.24 fish /m^2 compared to a mean 0.43 fish/m^2) concentrated in a few areas (i.e. under a downed tree near the stream bank), and subsequently more time was spent in these areas where the fish were easy to net. Thus, the population estimates of central stonerollers in these sites are likely to be an overestimation. Although the dace were also congregated in areas such as these, the patchy distribution did not effect the relationships between CPUE or density of dace caught on first pass and multiple-pass population estimates. This can be explained by the fact that the dace were usually much less evasive than the stonerollers. Therefore, when the dace were congregated in one area it didn't necessarily mean that I would capture many more than I would have with a less patchy distribution.

These differences between the correlations of the southern redbelly dace and the central stonerollers are likely attributed to the behavior of the fish. Southern redbelly dace are a pelagic species while central stonerollers are a benthic species. According to Zalewski (1983), capture efficiency for small benthic forms of Cyprinidae is low due to their tendency to remain near the bottom of the stream. If this is true, then it would be expected that the behavior of the stonerollers would make them more difficult to capture than the dace. Therefore, it is possible that at the few sites where stonerollers were concentrated in small areas of woody debris, an overestimation of the populations occurred because it was easier in these sites to capture stonerollers while it is usually very difficult to catch them. The index of CPUE is particularly vulnerable to this situation as it controls for time, and we had higher CPUE in those sites because we caught so many more fish from the concentrated area in a shorter amount of time.

These results are not necessarily inconsistent with those of Pusey et al. (1998) and Angemeier and Smogor (1995). Both studies suggest that using a single-pass electrofishing event does not adequately describe total fish assemblages, though neither discusses the use of a single-pass to predict population density of a single species. In this study, the fish assemblage of Kings Creek would not have been accurately predicted by a single-pass event because the effectiveness of the single-pass method differed from one species to the next. However, in this study it is clear that a single pass can provide a reliable index to southern redbelly dace population density. Jones and Stockwell (1995) strongly advise using a rapid-assessment technique such as this "to increase coverage (and thus overall precision)" of a study even though some precision would be lost for each population estimate at each site. It is likely that in streams similar to Kings Creek, the rapid-assessment techniques could be used for other common pelagic species and possibly common benthic species, depending on fish and stream characteristics. I would not recommend using a rapid-assessment technique for species that are not common.

I also expected that habitat variables such as stream depth and width and other physical habitat obstructions (woody debris, etc.) would affect probability of capture of fish species. However, this was not the case, most likely because the variability among sites was not great enough to document a relationship. As Figure 8 shows, sites with a large amount of woody debris had similar probability of capture for dace as sites with little woody debris. Also, as Figure 9 shows, the width of the site did not correlate to probability of capture for dace. This is surprising considering the bias in population estimates I experienced when the stonerollers congregated in certain habitats. However, this result is consistent with those of Pusey et al. (1998) who measured similar habitat parameters and found no relationships. In contrast, Kruse et al. (1995) found that stream width along with single-pass fish numbers showed a stronger relationship to estimated density from multiple passes than using only one-pass to predict density, indicating that the habitat was indeed affecting the probability of capture.

One possible explanation as to why the qualitative observations regarding stoneroller capture could not be documented quantitatively is that the heterogeneity of the sites could not be accurately measured. Although I could account for the area of the site covered with woody debris, my methods could not indicate the quality of the fish habitat. For instance, my methods could not differentiate between a large log in the middle of the stream in hot sunlight and a log near the bank of the stream under cover of vegetation. Although the logs may be of equal area, the one near to the bank is clearly of higher quality fish habitat. This problem was not mentioned in the other studies which examined fish habitat parameters and probability of capture(Pusey et al. 1998, Kruse et al. 1998). It would be useful to design a ranking system that would rank fish habitat as poor quality or high quality.

In the future, this rapid assessment procedure should be tested in other streams such as Kings Creek on other species besides trout. It is necessary to determine whether the high relationships for dace or other species would be found in other streams that have more habitat variation than Kings Creek. I also think that the methods should be revised so less sampling bias occurs (as with central stonerollers). Because fish were concentrated in certain areas, we spent more time shocking in those areas. To assure this doesn't happen, the team should try to cover a certain area in a more regular pattern. I also think that there should not be a maximum number of passes set. The population should be depleted until the researchers feel that they can obtain an accurate regression and population estimation. Finally, in any streams where block nets are possible, I highly suggest taking the time to set them up in order to close off the population. In some sites this would be next to impossible, but it would be very beneficial in those sites where it is possible. Clearly, with a few modifications, this procedure has the potential to save fishery researchers large amounts of time and money while allowing them more valid statistical studies.

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